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The effect of plants density and population on yield and yield components and forage in dual purpose cultivation of barley cultivars (*Hordeum vulgare* L.)

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Abstract

In order to study the effect of plant population and Density on the yield components and forage in dual cultivation of barley cultivars, a split plot experiment in the form of randomized complete block design with for replications was carried out in Khuzestan agricultural and natural resources research farm in 2011-2012. The main factor consisted of two barley cultivars (midday, 10th global) and the sub factor consisted of four levels of planting density (250, 350, 450, 550 seed per square meter). The results of the experiment showed that the effect of cultivar and planting density on grain yield was significant at 1% level. The interactive effect of cultivar and density on 1000-grain weight, biomass yield of final harvest time, forage, and harvest index was not significant. However, the difference between various cultivars in terms of total biomass yield was significant at 5% level. The highest rate of grain yield, biological yield, number of grains per area unit, and 1000-grain weight belonged to 10th global cultivar with density of 550 seeds per square meter. The interactive effect of cultivar and planting density on the yield of forage was not significant while the effect of planting density on forage was significant at 1% level. The highest forage yield belonged to 10th global cultivar with density of 550 seeds per square meter and the lowest yield belonged to midday cultivar with density of 250 seeds per square meter. The results of the experiment indicated that 10th global cultivar with high yield potential produced more vegetative organs and its early season vegetative growth was more than midday cultivar and consequently it had higher yield of forage, and also had produced more fertile tillers and foliages than the midday cultivar; moreover, it had higher forage and grain production potential than the midday cultivar while the midday cultivar had the lowest vegetative growth and its grain and forage production potential was less than 10th global cultivar.

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Introduction

Cereals as the main source of food supply for human beings and the major source of feeding livestock and also the raw material for some industries play a leading role in each country's economy. In fact, the first step towards each country's independence is the ability to produce food for its people. In order to increase crop production per area unit, it is necessary to improve breeding and farming operations and when these two are used together, it could be profitable (Ahmadi and Hossein Poor, 2012).

Like many other researchers, Ahmadi and Hossein Poor (2012) have reported that in order to achieve greater production per area unit, in addition to having good cultivars which are compatible with the environment plants reaction and their side requirements such as the number of plants per area unit are highly significant. Linderberg *et al* (2003) stated that different barley cultivars had different reactions to environmental conditions and planting dates. Cultivars with high harvest index are able mobilize more carbohydrates from green plants organs and thus increase the yield (Gobadi *et al.*, 2007).

Soleimani *et al* (2012) stated that in plant density, the plants entirely made use of water, air, light, soil in environmental conditions and the competition between or within the plants was minimized and the plants with density of 400 plants per square meter had the highest grain yield. The increase of applied seeds could increase the number of spikes per area unit but the number of seeds per spike will decrease. In fact, the relative compensation property between the yield components of wheat could minimize yield deficiency when a component is reduced.

Bavar (2008) stated that generally the dual purpose use of barley (simultaneous harvest of green fodder and grain) was not very common in different parts of the world especially in Europe, but much research has been done on other similar cereal crops particularly wheat, oats, and triticale. Traditional harvest of wheat and barley forage in the early stages of growth is common in Iran; by earlier sowing of them the farmers grow more wheat and barley before the winter chill and they provide a part of the forage needed for the livestock by grazing or harvesting green fodder in late winter or early spring. By doing research on the sowing of dual purpose wheat under different seed densities and nitrogen levels, Khalil *et al* (2011) showed that the grain yield was associated with the decrease of cutting delay so that most of the plants had the highest grain yield, tiller per plant, grain per spike, and 1000-grain weight in no forage cutting case. In another study, . Ghorbani *et al* (2010) reported that even though the harvest index increased as the grain yield increased, the proportion of such increase for biological yield was more than the increase of harvest index. The purpose of this experiment was to examine the effects of plant density in forage varieties barley and their interactions on yield, yield components and yield of barley has been compared to the best treatment obtaining maximal yield and economic benefit to farmers is recommended.

Materials and methods

To determine the optimum amount of seeds in cultivation of dual purpose barley, a split plot experiment in the form of randomized complete block design with for replications was carried out in Khuzestan agricultural and natural resources research farm located in southwest of Ahvaz in 2011-2012. The research field is located in an areas arid climate and semi-arid. Longitude, latitude and altitude of sea are 31° 20´ E, 48° 41´ N, and 20 m, respectively. The main factor consisted of two barley cultivars (midday, 10th global) and the sub factor consisted of four levels of planting density (250, 350, 450, 550 seed per square meter). Each sub plot included six lines as long as 6 m and 20cm spacing cultivation lines. To harvest the forage, after eliminating two marginal lines and half a meter from the top and bottom of each plot all the fresh forage was cut with a sickle 10 cm above the ground. Then the total forage of each plot was immediately weighed separately and put in plastic bags and the features were recorded and then each bag was sent to the laboratory to determine the weight of dry forage. At the end of growth stage, final harvest operation started and the final yield of each plot was measured in an area of 4 m2. At first, the harvested part was weighed as the biological yield (biomass of final harvest time) and then the grain yield and yield components were measured.

In order to measure the grain yield per square meter an area equal to 4 m2 was harvested after maturity stage and after threshing the spikes during the final harvest, the final product which was obtained was weighed. Harvest index for each experimental plot was calculated through dividing grain yield per square meter by dry biomass yield per square meter multiplied by 100.

To calculate the biomass of final harvest time, all the plants within an area of 1 square meter of the soil were harvested by a sickle and were packed and weighed separately. The total biomass was calculated after the harvest of all samples by adding the sum of the biomass of final harvest time to total biomass. The ANOVA test was done by means of statistical software of SAS and Duncan's multi range test at 5% level was used to compare the means.

Results and discussion

Number of spikes per square meter

The ANOVA results showed that the effect of cultivars on the number of spikes per square meter was significant at 5% level (table 1). The mean comparison of the number of spikes per square meter among the barley cultivars (table 2) showed that the highest and the lowest number of spikes per square meter belonged to 10th global cultivar by 459.75 spikes/m2 and midday cultivar by 288.63 spikes/m2 respectively. It seems like that 10th global cultivar was evaluated as having high potential and tolerant of dual purpose cultivation conditions. Dual purpose cultivation of barley caused a severe reduction in the number of spikes per square meter in midday cultivar.

Ahmadi and Hossein poor (2012) said that even though in low densities due to having sufficient space each single plant can produce more tillers, the increase of tillers in low densities cannot compensate for the reduction of the number of spikes per area unit in comparison to higher densities.

Soleimani *et al* (2012) stated that in plant density, the plants entirely made use of water, air, light, soil in environmental conditions and the competition between or within the plants was minimized and the plants with density of 400 plants per square meter had the highest grain yield. Nezami and Izadkhah (2011) stated that among the two-row and six-row cultivars, the production of more tillers was a distinctive feature of two-row barley cultivars in comparison to six-row cultivars and that is why two-row cultivar produced a larger number of spikes per plant. The ANOVA results of the effect of different density levels on the number of spikes per square meter were not significant (Table 1).

1000-grain weight

The ANOVA results showed that the effect of cultivar on the weight of 1000-grain was significant at 1% level (Table 1). In table (2), it is observed that the highest and the lowest weight of 1000-grain belonged to the 10th global cultivar by the average of 37.50 g and the midday cultivar by the average of 35.00 g respectively. The ANOVA results in table (1) showed that the effect of different levels of planting density on the weight of 1000-grain was significant at 1% level.

Dadashi *et al* (2011) believed that the reason of this matter was the reduction of grains share of assimilates. The average weight of 1000-grain is initially determined by the mobilization of assimilates into spikes between flowering and maturity stages. This, in turn, depends on the continuity of leaf area after flowering stage and photosynthetic activity of spike and also the source-target relationships.

Ahmadi and Hossein Poor (2012) said that the number of grains in two-row barley cultivars is fewer than the number of grains in six-row cultivars; therefore, more resources and photosynthetic assimilates are devoted to plant's reproductive organs.

The mean comparison of the effect of studied densities on the weight of 1000-grain showed that the highest and the lowest planting density belonged to the density of 250 seeds/m2 by 38.62 g and the density of 550 seeds/m2 by 31.25 g respectively (Table 2). As the planting density increased, less photosynthetic materials were devoted to filling the grains due to the increase of interplant and intra-plant competitions and ultimately the weight of 1000-grain decreased. Moreover, the decrease of 1000-grain weight in high densities could be related to lower carbohydrate supplies before pollination in stems containing spikes and higher breathing of crop in such densities which could decrease the continuity of leaf area and consequently limit grain filling. E'tesami *et al* (2009) got the same results in studying growth analysis and phonological changes of barley genotypes. Momtazi (2009) stated that the weight of 1000-grian in winter barley was more in lower densities and as the density increased it decreased. The ANOVA results of table (1) showed that the interactive effect of cultivar and different levels of density on 1000-grain weight was not significant.

Number of grains per square meter

The ANOVA results of table (1) showed that the effect of studied barley cultivars on the number of grains per square meter was significant at 1% level. The means comparison showed that the highest and the lowest number of grains per square meter belonged to the 10th global cultivar by the average of 7682 and the midday cultivar by the average of 6408 grains per square meter respectively (Table 2). It seems like that grain in each spike determines the major part of grain yield. Even though the number of spikes per square meter has serious negative effect on grains of each spike, the weight of grain has the lowest effect on the yield and the grain feeling rate depends on another important factor that is the number of grains per area unit. Giunta *et al* (2007) believed that the increase of grain yield in new cultivars was associated with the increase of the number of grains per square meter.

The ANOVA results showed that the effect of cultivation density on the number of grains per square meter was significant at 1% level (Table 1). The means comparison showed that the highest and the lowest number of grains per square meter belonged to the density of 550 seeds/m2 by the average of 7770 grains/m2 and the density of 250 seeds/m2 by the average of 6418 seeds/m2 respectively (Table 2). Accordingly, in most conditions the yield decreased during the grain filling period due to the reservoir restriction and the increase of reservoir power such as the number of grains/m2 could lead to the increase of grain yield. Therefore, the number of grain per square meter is an important trait in increasing grain yield.

The ANOVA results showed that the interactive effect of treatments on the number of grains per square meter was significant at 5% level (Table 1). The mean comparison of the interactive effects of studied cultivars and different levels of cultivation density on the number of grains per square meter showed that the highest and the lowest number of grains per square meter belonged to the 10th global cultivar with density of 550 seeds/m2 by the average of 8651 grains/m2 and the midday cultivar with density of 250 seeds/m2 by the average of5629 seeds/m2 respectively (Table 2). The increase of the number of grains per area unit is possible through the application of optimal crop management in each growth stage of barley and the number of fertile tillers actually determines the ultimate number of grains (Noor Mohammadi *et al*., 1998).

Number of grains per spike

The ANOVA results of table (1) showed that the effect of studied barley cultivars on the number of grains per spike was significant at 1% level. The means comparison (Table 2) showed that the highest and the lowest number of grains per spike belonged to the 10th global cultivar by the average of 27.56 grains/spike and the midday cultivar by the average of 25.87 grains/spike respectively. This trait could be mentioned as the difference between two-row and six-row cultivars so that six-row cultivars produced larger number of grains per spike in area unit which probably led to the increase of intra-plant competition during the formation of flower homes and the decrease of flower homes in spikelet and eventually the number of grains per spike. Nezami and IzadKhah (2011) observed a significant difference between the applied cultivars.

The ANOVA results (table 1) showed that the effect of planting density on the number of grains per spike was not significant. The interactive effect of the treatments on the number of grains per spike was not significant either (Table 2).

Grain yield

The ANOVA results of table (1) showed that the effect of cultivar on f grain yield was significant at 1% level. The means comparison showed that the highest and the lowest number of grain yield in the studied cultivars belonged to the 10th global cultivar by the average of 2795.06 kg/ha and the midday cultivar by the average of 2488.19 kg/ha respectively (Table 2). It seems like that the high grain yield in the 10th global cultivar could be associated with the higher number of spikes per area unit of this genotype in comparison to midday cultivar. Generally, any factor which increases the number of spikes per square meter will increase the final grain yield too. Therefore, barley cultivars have prepared the ground for the increase of the number of spikes per area unit by providing appropriate environment and this had led to the increase of grain yield of the cultivars. Nezami and IzadKhah (2011) reported that the significant difference between the cultivars could be related to higher biological yield and number of grains per spike in 6-row cultivar in comparison to 2-row cultivar.

The ANOVA results showed that the effect of different levels of density on the grain yield was significant at 5% level (Table 1). The mean comparison of different density levels showed that the highest and the lowest grain yield belonged to the density of 550 seeds/m2 by the average of 2889.9 kg/ha and the density of 250 seeds/m2 by the average of 2457.5 kg/ha (table 2). The reason could be due to the fact that as the density increased, the grain yield increased too which was due to higher biological yield, harvest index and the number of grains per spike in the highest grain yield in comparison to low densities. Moreover, the main reason of the highest grain yield in higher densities was the greater number of spikes in those densities. Ahmadi and Hossein Poor (2012) stated that the main reason of the difference between grain yields in different densities was associated with the number of per square meter, so that as the plan density increased the recent component significantly increased and devoted the most changes to it in comparison to other two yield components. Actually, the higher number of grains per spike and also the heavier weight of 1000-grain in low densities of plant could not compensate for the yield reduction due to fewer number of spikes per area unit.

The ANOVA results showed that the interactive effect of the treatments on grain yield was significant at 5% level (Table 1). The results were consistent with the findings of Mehrpooyan *et al* (2010).

Forage

The ANOVA results showed that the effect of the studied cultivars on the forage was significant at 5% level (Table 1).The mean comparison of the studied cultivars showed that the highest and the lowest yield of forage belonged to the 10th global cultivar by the average of 6338.3 kg/ha and the midday cultivar by the average of 3342.1 kg/ha (table 2). The reason of the difference between the forage in different cultivars could be due to the fact that the 10th global cultivar with high potential in terms of the yield of vegetative organs had higher production and its vegetative growth in early season has been more and consequently it has produced more green fodder while the midday cultivar had the minimum growth and had produced less forage.

The effect of different levels of cultivation density on forage was significant at 1% level (Table 1). The means comparison showed that among different levels of cultivation density the highest and the rate of forage belonged to the density of 550 seeds/m2 by the yield of 3783.3 kg/ha and the density of 250 seeds/m2 by the yield of 3055.6 kg/ha2 respectively (Table 2). Generally, as the plant density increased, the yield of fresh forage increases significantly which resulted from the increase of the number of plants per area unit and the increase of green fodder production in high density. Lak *et al* (2001) reported that as the cultivation density increased the rate of fresh forage of triticale increased too.

Doroodian *et al* (2011) reported that there was no correlation between the rate of harvested forage at the end of winter and the rate of grain yield decline due to the harvest.

Total biomass

The ANOVA results showed that the effect of the studied cultivars on total biomass was significant at 5% level (Table 1). The mean comparison of the studied cultivars showed that the highest and the lowest total biomass belonged to the 10th global cultivar by the yield of 10727.9 kg/ha and the midday cultivar by the yield of 10112.9 kg/ha (table 2). 10th global cultivar has higher grain yield and more forage in comparison to midday cultivar, so it seems like that this cultivar has a high potential for dual purpose cultivation.

The ANOVA results showed that the effect of different levels of cultivation density on total biomass was significant at 5% level (Table 1). The mean comparison of different density levels showed that the highest and the lowest total biomass belonged to the density of 550 seeds/m2 by the yield of 11236 kg/ha and the density of 250 seeds/m2 by the yield of 9740 kg/ha (table 2). It seems like that as the density increased the production biomass increased too. Even though the dry matter of each plant decreased as the number of plants increased in area unit, further number of plants led to the increase of production biomass yield. Rahimi *et al* (2012) got similar results. Mansoori far *et al* (1992) believed that as the density increased, the yield of production biomass increased too. Although dry mater of each plant decreased as the number of plants in area unit increased, higher number of plants led to the increase of the yield of production biomass per area unit.

Lak *et al* (2009) reported that the increase of forage yield in high densities was associated with the increase of the number of plants per area unit and the increase of vegetative growth in treatments with high density.

The ANOVA results showed that the interactive effect of cultivation density and studied cultivars on total biomass was very significant at 1% level (table 1).

Table 1. The ANOVA results of grain yield, yield components, forage, total produced biomass, biological yield, and harvest index of barley.

Total biomass	forage	Number of grains/spike	Number of grains/m2	1000-grain weight	Number of spikes/m2	Harvest index	Biomass of final harvest time	Grain yield	Degree Freedom	Sources of variation
1859758	1777662	10.36	1214970	19.5	4832.87	16.87	1105570	166987	3	block
3025800*	701520*	22.78**	1091588**	50.1**	234280.12*	60.50**	944281ns	753378**	1	cultivar
461579	481034	3.11	10863	4.83	7555.21	27.58	444819	223816	3	Error A
3146848**	761457**	2.03ns	2678431**	90.92**	11382.37ns	1.37ns	1865580*	290545*	3	Cultivation density
2943224*	13658ns	1.11ns	1896986*	2.58ns	1771.54ns	5.25ns	91388ns	302788*	3	Cultivar x cultivation density
600658	137546	2.10	494007	4.14	4761.59	4.95	468187	75697	18	Error (B)
7.44	10.63	5.42	9.98	5.61	18.44	5.75	10.01	10.41		Coefficient of variations

**: significant at 1% level; *: significant at 5% level; ns: non-significant.

Final harvest biomass (biological yield)

The ANOVA results showed that the effect of the studied cultivars on biological yield was not significant (Table 1). The ANOVA results showed that the effect of different levels of cultivation density on biological yield was significant at 5% level (Table 1). The mean comparison of different levels of cultivation density showed that the highest and the lowest rate of biological yield belonged to the density of 550 seeds/m2 by the yield of 7453.3 kg/ha and the density of 250 seeds/m2 by the yield of 6303.9 kg/ha (table 2). Therefore, as the cultivation density increased, the number of fertile tillers per area unit and the number of leaves and stems and consequently leaf area index and ultimately the grain yield increased too. Such changes would finally increase the biological yield. Also,(Bavar, 2008; Donaldson *et al*, 2001) reported that as the density increased, biological yield increased linearly.

Table 2. Mean comparison of yield and yield components of barley at different density levels of seed cultivation and cultivars.

Total biomass (kg/h)	forage (kg/h)	Number of grains /spike	Number of grains/m2	1000-grain weight(g)	Number of spikes /m2	Harvest index (%)	Biomass of final harvest time (kg/h)	Grain yield (kg/h)	treatments	
10112.9 b	3342.1 b	25.87 b	6408 b	35.00 b	288.63 b	37.49 b	6636.3 a	2488.19 b	midday	cultivar
10727.9 a	6338.3 a	27.56 a	7682 a	37.50 a	459.75 a	39.89 a	7006.7 a	2795.06 a	10th global	
9740 b	3055.6 b	27.1 a	6418 c	38.62 a	343.4 b	38.98 a	6303.9 b	2457.5 b	250	Cultivation density
10207 b	3540.9 a	27.0 a	6795 bc	37.62 a	347.0 b	38.02 a	6665.9 b	2534.1 b	350	
10498 ab	3581.0 a	26.7 a	7198 ab	37.50 a	382.0 ab	38.82 a	6916.6 ab	2685.3 ab	450	
11236 a	3783.3 a	26.0 a	7770 a	31.25 b	424.4 a	38.77 a	7453.3 a	2889.8 a	550	

The ANOVA results showed that the interactive effect of density and cultivar on biological yield was not significant (Table 1).

Harvest index

Harvest index expresses the relative distribution of assimilates between economic reservoir (grain) and other reservoirs available in plants. The ANOVA results showed that the effect of cultivar on harvest index was significant at 1% level (table 1). By studying the effects of for levels of density on the yield and yield components of barley in Ahvaz (200, 300, 400, and 500 plants/m2), (SabetMoghadam *et al.*, 2009) concluded that as density increased, the grain yield increased too so that the highest yield belonged to densities with 300 and 400 plants/m2, but in the density of 500 plants/m2, due to too much lodging and severe decrease of 1000-grain weight, grain yield and harvest index decreased.

The mean comparison of the studied cultivars showed that the highest and the lowest harvest index belonged to the 10th global cultivar by the average of 39.89% and the midday cultivar by the average of 37.49% (table 2).

The ANOVA results showed that the effect of cultivation density on harvest index was not significant (Table 1). Studies showed that in low densities due to the production of larger and heavier grains and the decrease of straw yield, the harvest index would increase. In fact, in lower densities the plant devotes its assimilates more to economic yield (grain) (AsadolahZadeh, 2009).

The ANOVA results showed that the interactive effect of cultivar and cultivation density on harvest index was not significant (Table 1).

Conclusion

Because of having more leaf area index, 10th global cultivar got more dry matter during the growth stage as the photosynthetic activity increased. Therefore, the grain yield in this cultivar increased in comparison to the other one. In fact, this cultivar is a strong species for dual purpose cultivation of barley in weather conditions of Ahvaz. If dual purpose cultivation of barley is going to be studied in future research it is suggested to study different amounts of seed in case of livestock grazing or harvesting the forage by machines.

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